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METHOD AND SYSTEM FOR FORMING MAIN AND SIDE BEAMS OF LIGHT FOR MULTIPLE DISC FORMATS

Cross-Reference to Related Application(s)

The present application claims priority under 35 U.S.C. §119 to Korean Patent Application No. 2003-0032392, filed on May 21, 2003, which is incorporated herein by reference in its.entirety.

Technical Field

The present invention relates generally to optical disc technology, and more particularly, to forming side beams of light that are each displaced from a main beam of light within a servo tolerance range for multiple disc formats.

Background of the Invention

The present invention is described for directing main and side beams of light onto an optical disc within an optical pickup. However, the present invention may in general be used for any application having main and side beams of light directed onto an optical disc.

Fig. 1 shows a block diagram of an optical pickup 100 with light generated at a laser diode 102. The light from the laser diode 102 passes through a grating 104 that splits such light into a main beam and two side beams. The main and side beams of light are reflected by a beam splitter 106 to be directed through a collimating lens 108. The beams of light from the collimating lens 108 are focused by an objective lens 110 onto an optical disc 112.

The beams of light are then reflected from the optical disc 112 and pass back through the objective lens 110 and the collimating lens 108. Such reflected beams of light pass through the beam splitter 106 to reach a second objective lens 114. The second objective lens 114 focuses the reflected beams of light onto a photo-detector 116.

Fig. 2 shows a magnified view of tracks on the optical disc 112 having a plurality of alternating lands 122 and grooves 124 along the radial direction of the optical disc 112. Fig. 3 shows a cross-sectional view of such lands 122 and grooves 124 across line I-I in

Fig. 2. When the optical disc 112 is a DVD-ROM disc, data is recorded with data pits (illustrated as blackened areas in Fig. 2) on the grooves 124.

Referring to Fig. 4, a main beam 126 is directed onto a groove, and first and second side beams 128 and 130 are directed onto the adjacent lands. The first side beam 128 lags the main beam 126, and the second side beam 130 leads the main beam 126. The main and side beams 126, 128, and 130 are formed by the components of the optical pickup 100 of Fig. 1.

Fig. 5 shows an error signal calculator 132 that uses the main and side beams 126, 128 and 130 reflected from the optical disc 112 for calculating a DPP (differential push-pull) error signal. First, second, and third photo-detector units 134, 136, and 138 are disposed on the photo-detector 116 in Fig. 1. The first photo-detector unit 134 is situated on the photo-detector 116 to detect the intensity of the main beam 126 reflected from the optical disc 112. The second photo-detector unit 136 is situated on the photo-detector 116 to detect the intensity of the first side beam 128 reflected from the optical disc 112. The third photo-detector unit 138 is situated on the photo-detector 116 to detect the intensity of the second side beam 130 reflected from the optical disc 112.

The values a, b, c, and d from the first photo-detector unit 134 represent the intensity of reflected light for the four quadrants of the main beam 126, as illustrated in Fig. 5. The values e and f from the second photo-detector unit 136 represent the intensity of reflected light for the two halves of the first side beam 128, as illustrated in Fig. 5. The values g and h from the third photo-detector unit 138 represent the intensity of reflected light for the two halves of the second side beam 130, as illustrated in Fig. 5.

A plurality of calculating units 140, 142, 144, 146, and 148 and a gain unit 150 are used to generate a DPP (differential push-pull) error signal as follows:

$$DPP = MPP - G(SPP1 + SPP2);$$

with $MPP = [(b+d) - (a+c)]$; $SPP1 = (f - e)$; $SPP2 = (h - g)$; and G being a gain value. The DPP, MPP, SPP1, and SPP2 signals are illustrated in Fig. 6 with a graph of the amplitudes of such signals as the main and side beams 126, 128, and 130 scan across the radial direction of the optical disc 112.

The DPP error signal is used as a tracking error signal by a tracking servo for the

optical pickup 100 of Fig. 1. Generally, the intensity of light reflected from a land is greater than that reflected from a groove. For proper tracking, the main beam 126 is desired to be centered on the groove, and the side beams 128 and 130 are desired to be centered on the adjacent lands.

Referring to Figs. 4 and 5, if the main and side beams 126, 128, and 130 are shifted undesirably toward the right, (b+d) > (a+c), e > f, and g > h such that the DPP error signal becomes more positive. On the other hand, if the main and side beams 126, 128, and 130 are shifted undesirably toward the left, (a+c) > (b+d), f > e, and h > g such that the DPP error signal becomes more negative. Such change in the DPP error signal is used by the tracking servo as feedback for maintaining the desired radial position of the main and side beams 126, 128, and 130, as known to one of ordinary skill in the art.

Fig. 7 illustrates the alternating lands and grooves (labeled as L and G, respectively, in Fig. 7) of the optical disc 112 with the main and side beams 126 and 130. The first optical disc 112 has a first disc format with a first track pitch 152. Fig. 7 also shows another optical disc 154 having a second disc format with a second track pitch 156.

When the first and second disc formats are different, the first and second track pitches 152 and 156 are different. For example, the first optical disc 112 has a DVD-ROM format with the first track pitch 152 of 0.37μm while the second optical disc 154 has a CD (compact disc) format with the second track pitch 156 of 0.8μm.

In Figs. 4 and 7, the side beams 128 and 130 are each placed from the main beam 126 on the optical disc 112 with a displacement equal to the first track pitch 152. Such main and side beams 126, 128, and 130 of Fig. 4 are used to generate the DPP error signal as illustrated in Fig. 6. However, when such beams 126, 128, and 130 are also used for the second optical disc 154 having the different second disc format, the side beams 128 and 130 are no longer centered about the adjacent lands. As a result, the SPP1and SPP2 signals are undesirably phase-shifted with respect to the MPP signal such that the amplitude of the DPP signal is decreased as illustrated in Fig. 8. If the DPP signal is decreased too much, the tracking servo using the DPP signal becomes unstable.

Each of the side beams 128 and 130 is desired ideally to be placed with a positional phase-shift of 180° from the main beam 126 with the center of one groove to

the center of another groove defining one cycle of 360°. In addition, the tracking servo that uses the DPP error signal typically has a servo tolerance range of the positional phase-shift of each of the side beams 128 and 130 from the main beam 126 for stable operation. An example of such a servo tolerance range is ±40° from 180°. If the side beams 128 and 130 are not placed within such a servo tolerance range, the tracking servo using the DPP signal becomes unstable.

Nevertheless, an optical pickup that may be used for a plurality of different disc formats is desired. Thus, a mechanism is desired for forming main and side beams positioned within the servo tolerance range for a plurality of different disc formats.

Summary of the Invention

Accordingly, in a general aspect of the present invention, a least common multiple of a plurality of track pitches for a plurality of disc formats is determined for placing the side beam from the main beam.

In a general embodiment of the present invention, in a method and system for forming light beams onto a disc for a plurality of disc formats, a main beam is directed onto the disc. A side beam is directed onto the disc with a displacement from the main beam. The displacement is a LCM (least common multiple) distance of respective track pitches for the plurality of disc formats.

In a further embodiment of the present invention, the LCM distance is within a respective tolerance range from a respective integer multiple of a respective track pitch for each of the disc formats.

In another embodiment of the present invention, another side beam is directed onto the disc on another side of the main beam with substantially the same displacement from the main beam. The main and side beams reflected from the disc may be used for generating a tracking error signal such as a DPP (differential push-pull) error signal.

In a further embodiment of the present invention, the main and side beams are generated with light from a laser diode passing through a grating. In that case, at least one of a pitch of the grating and a distance of the laser diode to the grating is adapted to affect the displacement to be the LCM distance.

In this manner, a side beam has positional phase-shift from the main beam within the servo tolerance range for each of the multiple disc formats. The tracking servo uses such main and side beams with stable operation for the multiple disc formats.

These and other features and advantages of the present invention will be better understood by considering the following detailed description of the invention which is presented with the attached drawings.

Brief Description of the Drawings

Fig. 1 shows components of a conventional optical pickup, according to the prior art;

Fig. 2 shows lands and grooves for an example optical disc, according to the prior art;

Fig. 3 shows a cross-sectional view of the optical disc of Fig. 2, according to the prior art;

Fig. 4 shows main and side beams directed onto the disc of Fig. 2, according to the prior art;

Fig. 5 shows a tracking error signal calculator using the main and side beams reflected from the optical disc of Fig. 4, according to the prior art;

Fig. 6 shows error signals generated by the tracking error signal calculator of Fig. 5, according to the prior art;

Fig. 7 shows example optical discs with different disc formats with different track pitches, according to the prior art;

Fig. 8 shows the error signals of Fig. 6 with a DPP error signal undesirably decreased in amplitude when the side beams are not centered about adjacent lands on the optical disc, according to the prior art;

Fig. 9 illustrates placing each side beam from a main beam within a servo tolerance range for multiple disc formats, according to an example embodiment of the present invention;

Fig. 10 shows cross-sectional views of lands and grooves for optical discs of multiple disc formats;

Fig. 11 shows components of a system for placing each side beam from a main beam within a servo tolerance range for multiple disc formats, according to an example embodiment of the present invention;

Fig. 12 shows a flowchart of steps during operation of the system of Fig. 11, according to an example embodiment of the present invention;

Fig. 13 shows a table of odd-integer multiples of respective track pitches for multiple disc formats used according to an example embodiment of the present invention;

Fig. 14 shows a table for determining a displacement of the side beam from the main beam to be a LCM (least common multiple) distance, according to an example embodiment of the present invention;

Fig. 15 shows a table of different servo tolerance ranges for the multiple disc formats, according to an example embodiment of the present invention; and

Figs. 16 and 17 each illustrate a side beam being outside of the tracks of an optical disc.

The figures referred to herein are drawn for clarity of illustration and are not necessarily drawn to scale. Elements having the same reference number in Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17 refer to elements having similar structure and function.

Detailed Description

The present invention is described for directing main and side beams of light onto an optical disc within an optical pickup. However, the present invention may in general be used for any application having main and side beams of light directed onto an optical disc.

Fig. 9 illustrates forming a main beam 203 and side beams 205 and 207 for optical discs of multiple disc formats, according to a general embodiment of the present invention. A first optical disc 202 has a first disc format with a first track pitch TP1, and a second optical disc 204 has a second disc format with a second track pitch TP2.

Additionally in Fig. 9, the side beams 205 and 207 are each displaced from the main beam 203 by a LCM (least common multiple) distance in the radial direction of the

optical discs 202 and 204. Furthermore, the LCM distance has a relationship to the first and second track pitches as follows:

$$LCM = x*TP1 = y*TP2$$

with x and y each being an odd integer. In the example illustration of Fig. 9, x=5, and y=3. With such a relationship, the main and side beams are each substantially centered about a respective one of a land or a groove for both of the first and second optical discs 202 and 204 (with the lands and grooves being labeled as alternating "L" and "G" in Fig. 9).

The side beams 205 and 207 are each desired ideally to be placed with a positional phase-shift of 180° from the main beam 203 with the center of one groove to the center of another groove defining one cycle of 360°. With the side beams 205 and 207 being displaced from the main beam 203 by the LCM distance, the side beams 205 and 207 are phase-shifted by 180° from the main beam 203 for both the first and second optical discs 202 and 204 having the different disc formats.

Fig. 10 illustrates cross-sectional views of optical discs having lands and grooves for different disc formats. An optical disc 206 with a CD (compact disc) format has data pits formed on lands, and the track pitch for the CD format is 0.8μm. For tracking in the CD format, a main beam is directed onto a land, and side beams are directed onto the adjacent grooves (as illustrated by the circles marked "M" and "S" in Fig. 10).

An optical disc 208 for a DVD-RAM format in Fig. 10 has data pits formed on lands and grooves, and the track pitch for the DVD-RAM format is 0.615μm. For tracking in the DVD-RAM format, a main beam is directed onto a groove, and side beams are directed onto the adjacent lands.

An optical disc 210 for a DVD-R,RW (DVD-Read, Read/Write) format in Fig. 10 has data pits formed on lands, and the track pitch for the DVD-R,RW format is 0.37μm. For tracking in the DVD-R,RW format, a main beam is directed onto a land, and side beams are directed onto the adjacent grooves.

An optical disc 212 for an AOD (advanced optical disc) format in Fig. 10 has data pits formed on lands and grooves, and the track pitch for the AOD format is 0.34μm. For tracking in the AOD format, a main beam is directed onto a land, and side beams are

directed onto the adjacent grooves.

An optical disc 214 for a blue light format in Fig. 10 has data pits formed on lands, and the track pitch for the blue light format is 0.18μm. For tracking in the blue light format, a main beam is directed onto a land, and side beams are directed onto the adjacent grooves.

Similarly, the optical disc 112 of a DVD-ROM format in Figs. 2, 3, and 6 has data pits formed on grooves, and the track pitch for the DVD-ROM format is 0.37μm. For tracking in the DVD-ROM format, a main beam is directed onto a groove, and side beams are directed onto the adjacent lands. The different optical discs 112, 206, 208, 210, 212, and 214 for such different disc formats are known to one of ordinary skill in the art.

Fig. 11 shows a system 220 for generating main and side beams directed onto an optical disc 222 that has any of a plurality of disc formats. The system 220 includes a laser diode 224 for generating light and includes a grating 226 for splitting the light from the laser diode 224 into main and side beams (similar to the main and side beams 203, 205, and 207 of Fig. 9). The main and side beams from the grating 226 are reflected by a beam splitter 228 to be directed to a collimating lens 230. The collimating lens 230 collimates the main and side beams toward an objective lens 232 that focuses the main and side beams onto the optical disc 222.

The main and side beams are then reflected from the optical disc 222 and pass back through the objective lens 232 and the collimating lens 230. Such reflected beams of light pass through the beam splitter 228 to reach a second objective lens 234. The second objective lens 234 focuses the reflected main and side beams onto a photo-detector 236. The photo-detector 236 is coupled to a tracking servo 238 that includes an error signal calculator 240 and a data processor 242.

Fig. 12 illustrates a flowchart of steps during operation of the system 220 of Fig. 11 for directing the main and side beams onto the optical disc 222. Given a plurality of possible disc formats for the optical disc 222, a table of Fig. 13 is used to determine a LCM (least common multiple) distance for such multiple disc formats (step 252 of Fig. 12). The table of Fig. 13 lists the respective track pitch for each of the possible disc formats including the CD format, the DVD-RAM format, the DVD ROM/R,RW format,

the AOD format, and the blue light format.

In addition, the table of Fig. 13 lists odd-integer multiples of the respective track pitch for each of the disc formats. Referring to the example of Fig. 9, a track pitch is the distance from the middle of a groove to the middle of the adjacent land. Referring to the cross-sectional views for the disc formats in Figs. 3 and 10, when the main beam is placed on a groove, the side beams are placed on lands. Alternatively, when the main beam is placed on a land, the side beams are placed on grooves.

Thus, the table of Fig. 13, which shows possible displacements of the side beam from the main beam, lists odd integer multiples of the track pitch. Displacement of the side beam from the main beam by an even integer multiple of a track pitch would undesirably result in placement of the main and side beams onto either all lands or all grooves. However, the present invention may also be practiced when the LCM distance is even integer multiples of the track pitches for applications where the main and side beams are desired to be placed onto all lands or all grooves.

Referring to Figs. 13 and 14, from such a table of Fig. 13, the LCM distance is determined for any combination of the disc formats desired for the optical disc 222. For example, referring to Figs. 13 and 14, assume that the optical disc 222 is desired to have any of the DVD ROM/R,RW format with a first track pitch $TP1=0.37\mu m$ and the DVD RAM format with a second track pitch $TP2=0.615\mu m$. In that case, from the table of Fig. 13, the LCM distance is determined to be 1.8475 which is the average of $5*TP1$ and $3*TP2$ since $5*TP1 \approx 3*TP2 \approx$ LCM distance.

In Fig. 9, the first optical disc 202 has the DVD ROM/R,RW format with the first track pitch $TP1=0.37\mu m$, and the second optical disc 204 has the DVD RAM format with a second track pitch $TP2=0.615\mu m$. Also in Fig. 9, the side beams 205 and 207 are each displaced from the main beam 203 by the LCM distance $\approx 3*TP2 \approx 5*TP1$. Referring to Figs. 9, 11, and 12, at least one of the pitch of the grating 226 and a distance 244 between the laser diode 224 and the grating 226 is adapted to affect the displacement of each of the side beams 205 and 207 from the main beam 203 such that the LCM distance $\approx 3*TP2 \approx 5*TP1$ (steps 254 and 256 in Fig. 12).

Referring back to Figs. 13 and 14, alternatively, assume that the optical disc 222 of

Fig. 11 is desired to have any of the DVD ROM/R,RW format with a first track pitch TP1=0.37μm and the CD format with a second track pitch TP2=0.8μm. In that case, from the table of Fig. 13, the LCM distance is determined to be 4.035 which is the average of 11*TP1 and 5*TP2 since 11*TP1≈ 5*TP2 ≈ LCM distance.

In a further alternative, assume that the optical disc 222 of Fig. 11 is desired to have any of the DVD ROM/R,RW format with a first track pitch TP1=0.37μm and the blue light format with a second track pitch TP2=0.18μm. In that case, from the table of Fig. 13, the LCM distance is determined to be 4.105 which is the average of 11*TP1 and 23*TP2 since 11*TP1≈ 23*TP2 ≈ LCM distance.

In a final alternative example, assume that the optical disc 222 of Fig. 11 is desired to have any of the DVD ROM/R,RW format with a first track pitch TP1=0.37μm, the DVD RAM format with a second track pitch TP2=0.615μm, and the CD format with a third track pitch TP3=0.8μm. In that case, from the table of Fig. 13, the LCM distance is determined to be 5.562 which is the average of 15*TP1, 9*TP2, and 7*TP3 since 15*TP1≈ 9*TP2 ≈ 7*TP3 ≈ LCM distance.

Generally, the LCM distance between each of the side beams and the main beam is a respective odd integer multiple of a respective track pitch that is within a respective servo tolerance range from the LCM distance, for each of the multiple disc formats. Fig. 15 shows a table of the respective servo tolerance range for each of the disc formats.

Referring to the example of Fig. 9, each of the side beams 205 and 207 is desired ideally to be placed with a positional phase-shift of 180° from the main beam 203 with the center of one groove to the center of another groove (or the center of one land to the center of another land) defining one cycle of 360°. The tracking servo 238 that uses the DPP error signal typically has a servo tolerance range of the positional phase-shift of each of the side beams 205 and 207 from the main beam 203 for stable operation. An example of such a servo tolerance range is ±40° from 180°. If the side beams 205 and 207 are not placed within such a servo tolerance range for a disc format, the tracking servo 238 using the DPP signal becomes unstable.

Referring to the table of Fig. 15, the CD format has a servo tolerance range of ±(0.8μm*40/180) = ±0.178μm, when the servo tolerance range is ±40° from 180°.

Similarly for this example servo tolerance range, the DVD RAM format, the DVD ROM/R,RW format, the AOD format, and the blue light format each have a respective servo tolerance range of ±0.137μm, ±0.082μm, ±0.076μm, and ±0.040μm.

Referring to the tables of Figs. 14 and 15, the respective odd integer multiple of the respective track pitch is within such a respective servo tolerance range from the average LCM for each row of the table of Fig. 14. For example, in the first row of Fig. 14, the respective odd integer multiple, 5*TP1, for the DVD ROM/R,RW format is 1.85 which is within the respective servo tolerance range of ±0.082μm from the average LCM of 1.8475. Similarly in that first row, the respective odd integer multiple, 3*TP2, for the DVD RAM format is 1.845 which is within the respective servo tolerance range of ±0.137μm from the average LCM of 1.8475.

In the example of the second row of Fig. 14, the respective odd integer multiple, 11*TP1, for the DVD ROM/R,RW format is 4.07 which is within the respective servo tolerance range of ±0.082μm from the average LCM of 4.035. Similarly in that second row, the respective odd integer multiple, 5*TP2, for the CD format is 4.0 which is within the respective servo tolerance range of ±0.178μm from the average LCM of 4.035.

In the example of the third row of Fig. 14, the respective odd integer multiple, 11*TP1, for the DVD ROM/R,RW format is 4.07 which is within the respective servo tolerance range of ±0.082μm from the average LCM of 4.105. Similarly in that third row, the respective odd integer multiple, 23*TP2, for the blue light format is 4.14 which is within the respective servo tolerance range of ±0.040μm from the average LCM of 4.105.

In the example of the fourth row of Fig. 14, the respective odd integer multiple, 15*TP1, for the DVD ROM/R,RW format is 5.55 which is within the respective servo tolerance range of ±0.082μm from the average LCM of 5.562. Similarly in that fourth row, the respective odd integer multiple, 9*TP2, for the DVD RAM format is 5.535 which is within the respective servo tolerance range of ±0.137μm from the average LCM of 5.562. Additionally in that fourth row, the respective odd integer multiple, 7*TP3, for the CD format is 5.6 which is within the respective servo tolerance range of ±0.178μm from the average LCM of 5.562.

In this manner, the average LCM value in the table of Fig. 14 is used for the LCM

distance between each of the side beams and the main beam in the system 220 of Fig. 11. Thus, the positional phase shift between each of the side beams and the main beam is within the servo tolerance range for stable operation of the tracking servo 238 for the desired multiple disc formats of the optical disc 222.

In another embodiment of the present invention, because the side beams are displaced from the main beam with integer multiples of the track pitch, one of the side beams may be placed outside the tracks of the optical disc 222. Referring to Figs. 11, 12, 16, and 17, the data processor 242 within the tracking servo 238 determines the occurrence of such a situation (step 258 of Fig. 12).

In Fig. 16, the optical disc 222 has tracks defined by an inner boundary 272 and an outer boundary 274 in the radial direction of the optical disc 222. Fig. 16 illustrates the situation when a side beam 270 is outside the outer boundary 274 of the tracks of the optical disc 222. Fig. 17 illustrates the situation when a side beam 276 is outside the inner boundary 272 of the tracks of the optical disc 222. In either case, the data processor 242 keeps track of the position of the main beam and the displacement of the side beams from the main beam to determine when the situations of Figs. 16 and 17 occur.

The situation of a side beam being outside of the tracks of the optical disc 222 may be undesired. In that case, the displacement between each of the side beams and the main beam is selected to be the minimum of any of the possible LCM distances that are within the servo tolerance range for the desired multiple disc formats. With such a minimum LCM distance, the occurrence of one of the side beams being outside the tracks of the optical disc 222 is minimized since the side beams are placed as close to the main beam as possible.

However, the present invention may be generally used with any LCM distance between each of the side beams and the main beam as long as the LCM distance is within a respective servo tolerance range from a respective odd integer multiple of a respective track pitch for each of the desired multiple disc formats. Any such LCM distance that is within the servo tolerance range results in stable operation of the tracking servo for the multiple disc formats.

Thus, the term "LCM distance" is generally defined herein as any LCM distance

that is within a respective servo tolerance range from a respective odd integer multiple of a respective track pitch for each of the desired multiple disc formats. In a general embodiment of the present invention, each of the side beams is displaced from the main beam on the optical disc by the LCM distance in the radial direction of the optical disc.

In any case, if the side beams are within the tracks of the optical disc 222, the data processor 242 controls the error signal calculator 240 to determine the tracking error signal using all of the main and side beams reflected from the optical disc 222, such as for calculating the DPP signal in Fig. 5 for example (step 260 of Fig. 12). On the other hand, if a side beam is determined to be outside the tracks of the optical disc 222 as illustrated in Figs. 16 or 17, the data processor 242 controls the error signal calculator 240 to determine the tracking error signal using only the main beam reflected from the optical disc 222 (step 262 of Fig. 12). An example mechanism for generating a tracking error signal with only the main beam reflected from the optical disc 222 using the PP (push-pull) method is disclosed in U.S. Patent No. 6,580,670.

The foregoing is by way of example only and is not intended to be limiting. For example, the present invention is described for directing main and side beams of light onto the optical disc 222 within an example optical pickup illustrated in Fig. 11. However, the present invention may in general be used for any application having main and side beams of light directed onto an optical disc.

In addition, any number as illustrated and described herein is by way of example only. For example, the present invention may be used for forming both of the side beams 205 and 207 in Fig. 9 that are each displaced from the main beam 203 by the LCM distance. In that case, the side beams 205 and 207 are placed on opposite sides of the main beam in an example embodiment. Alternatively, the present invention may be used for an application using one of the side beams 205 or 207 that is displaced from the main beam 203 by the LCM distance. The present invention may be generalized to using any number of side beams displaced from the main beam by the LCM distance.

The present invention is limited only as defined in the following claims and equivalents thereof.